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(54) Title: METHOD AND APPARATUS SUPPORTING TDD/TTY MODULATION OVER VOCODED CHANNELS

(57) Abstract: A method used to encode/decode a low activity communication signal - such as a Baudot tone - for transmission over a telecommunications system (100). The telecommunications system (100) may include any number of wireless links. Once the system (100) is noticed that a low activity signal needs to be transmitted, each vocoder used in the system (100) to encode/decode the signal performs a unique encoding/decoding process. In one embodiment, frames containing errors adversely affecting a signal are delivered to the vocoder and the "soft bits" contained therein are used to determine the original signal transmitted. In another embodiment, encoding of the signal may include encoding the signal using redundancy with the encoded signal being spread across multiple vocoder frames.

METHOD AND APPARATUS SUPPORTING TDD/TTY MODULATION OVER VOCODED CHANNELS

BACKGROUND OF THE INVENTION

I. Field of the Invention

Generally, the present invention relates to the field of telecommunication devices for the deaf (TDDs) or text telephone yokes (TTYs). More particularly, the invention relates to modification of standard vocoder operation to enable reliable transport of TDD/TTY signals within a telecommunication system. The system may include wireless links.

II. Description of the Related Art

Many deaf or hearing-impaired people use communication terminals specifically constructed and designed to enable them to communicate over standard telephone lines. Such devices, referred to as telecommunication devices for the deaf (TDDs) or Text Telephone Yokes (TTYs), are collectively referred to as TDDs in this application. Typically, TDDs include a keyboard and a display connected to a telephone via a modem (modulator/demodulator). The modem is built into the TDD and is either directly connected to a telephone line or coupled by an acoustic coupler to a normal telephone handset. TDDs are capable of transmitting information over telephone lines by means of coded tones to other TDDs connected at opposite ends of the telephone line through another modem. These tones are referred to as low activity communications because the frequency and amplitude envelopes remain relatively constant.

The code and protocol that is in widespread conventional use for TDD communications is an idiosyncratic one. The code set, known as Baudot, and the communication protocol (TDD protocol) evolved historically at a time when many telecommunication devices for the deaf were based on mechanical or electromechanical devices rather than electronic devices. Accordingly, the TDD protocol was constructed for a set of constraints that no longer are relevant to

present day devices. Those constraints work to create a code protocol and a telecommunication network of users and devices operating under that protocol, that is somewhat antiquated.

Traditionally, TDD communications are conducted at 50 Baud (45.5 Baud in some countries), representing a transfer of 6 characters per sec. Other protocols now available for TDD communications incorporate higher Baud rates, such as the ASCII (American Standard Code Information Interchange) and enhanced Baudot protocols. Regardless, a normal TDD communication character set consists of characters that are 5 bits long. These characters are analogous to a letter in an alphabet where each letter represents a word or idea. A character is grouped with overhead information bits prior to transfer, where each group of bits to be transferred has a duration or unit interval equal to 22 milliseconds. For example, under conventional TDD protocol, a group of bits to be transferred comprises 8 bits: a start bit (one source or zero bit), five bits representing the character, and at least one and 1/2 bits marking the stop point of the transfer group.

Compared to modern telecommunication systems, TDD transmissions occur at a snail's pace. A bigger problem is that TDD signals are substantially constant. These slow paced, monotone signals can create havoc in digital telecommunication systems that transmit higher activity signals at very high rates, and especially in telecommunication systems that include wireless links. One example of such a telecommunication system is a code division multiple access (CDMA) system having a large number of wireless subscriber units. Each subscriber unit has a transceiver and communicates within the system through satellite repeaters or terrestrial stations referred to as cells. Each cell includes a physical plant called a base station. A cell covers a limited geographic area and routes calls carried over subscriber units to and from the telecommunication network via a mobile switching center. When a subscriber moves into the geographic area of a new cell, the routing of that subscriber's call may be eventually made through the new cell by a process called a "handoff."

A subscriber unit, generically referred to as a cell phone, transmits a signal that is received by a base station. The signal is relayed to a mobile switching center that routes the signal to a public switched telephone network (PSTN) including telephone lines or other subscriber units. Similarly, a signal may be transmitted from the PSTN to a subscriber unit via a base station and a mobile switching center

The interface between the subscriber unit and the base station is referred to as the air interface. The telecommunications industry association (TIA) has provided a standard for CDMA call processing on the air interface entitled "IS-95 Mobile Station - Base Station Compatibility Standard for Dual Mode Wideband Spread Spectrum Cellular System." Addendum to IS-95 are provided as Telecommunications Service Bulletins (TSB). The standard IS-95 + TSB74 includes provisions for service negotiation on the air interface and is incorporated herein by reference.

Service negotiation is critical to successfully transmit any communication, especially a low activity TDD communication, over a digital telecommunication system. One problem with modern systems, including the one described above, is that a vocoder – a device used in the system to encode a voice or TDD analog signal into a digital signal, and to decode a digital signal into a voice or TDD analog signal– has difficulty in handling the substantially monotone signal and slow speed dictated by the TDD protocol. In current systems, a low activity communication signal such as a TDD communication would probably be treated by the vocoder as background noise or signal interference and be disregarded.

What is needed is an invention that can easily be integrated into existing communication systems and can be capable of reducing frame error rates by invoking a protocol to be used by the vocoders during transmission of the low activity communication signal.

The invention should be compatible with wireless telecommunication modulation systems, such as CDMA systems, servicing large numbers of

system users. A more robust discussion of CDMA systems and techniques used in multiple access communication systems may be found in U.S. Pat. No. 4,901,307, entitled "SPREAD SPECTRUM MULTIPLE ACCESS COMMUNICATION SYSTEM USING SATELLITE OR TERRESTRIAL REPEATERS," assigned to the assignee of the present invention and incorporated by reference herein. Further, the invention should also be compatible with other modulation systems and techniques used in other types of communication systems, such as time division multiple access (TDMA), frequency division multiple access (FDMA), and amplitude modulation (AMPS) schemes.

SUMMARY OF THE INVENTION

Broadly, the present invention involves the modulation of a low activity communication by a telecommunication system using encoded signals and increased transmission power levels. More particularly, the invention concerns a method that uses specialized encoding, decoding, or both, on a low activity communication signal to minimize a transmitted signal's frame error rate. The invention also provides for decoding a low activity signal by looking at "soft bits" contained in erred frames, or in frames adjacent to an erred frame, in an attempt to determine the content of the original frame.

Certain disclosed embodiments of the invention provide unique decoding methods for a TDD signal that was encoded using standard encoding protocol. In one embodiment, the decoder may compare a frame containing transmission errors (erred frame) with a vocoded frame from a known TDD signal and determine the most likely vocoded frame that was transmitted. In another embodiment, the decoder may review adjacent frames to determine the most likely vocoded frame that was transmitted but received in error. In yet another embodiment, the decoder can be modified to include a signal enhancer or repeater that "cleans up" corrupted bits in the transmitted frame before the decoding methods are applied upon the transmitted frames. And although a TDD communication is discussed throughout this application, it should be

understood that any slow or low activity communication may be transmitted using this invention.

Another embodiment of the invention provides for decoding as discussed above but invokes vocoder parameters that are different from standard vocoder parameters. When a TDD signal is received, the encoder switches to "Baudot encoding mode," notices the decoder of the protocol change, and uses channel coding redundancy to further improve the decoder's chances of determining the correct TDD signal sent even if it is contained in a bad frame. This version of the invention replaces standard vocoder parameters with vocoder "signatures" that are better spaced apart, thus making it easier to distinguish between tones.

Another version of the invention provides for encoding a TDD signal in vocoder frames using redundancy, but doing the encoding across numerous vocoder frames. The information is interleaved across "N" frames so that if a frame is lost, the decoder can extract necessary information from adjacent frames to determine the content of the lost frame.

Yet another version of the invention provides a cost-efficient system for combining the aforementioned encoding and decoding methods of the invention with methods for controlling transmission power levels. Modifying the design of a standard vocoder chipset within a mobile station is expensive, which could bar the implementation of the aforementioned encoding and decoding methods. However, a communication system can be implemented wherein the aforementioned methods are utilized in the system's base stations, but not in the mobile stations. Frame error rates for low activity communication signals transmitted from the base station to the unmodified vocoder in a mobile station can be minimized using methods for controlling transmission power levels.

The invention provides its users with numerous advantages. One advantage is that a TDD message can be transmitted using a digital transmission medium having wireless links. Yet another advantage is that a

TDD device can be connected to a mobile device or subscriber's unit, such as a digital cellular telephone, connected to the telecommunications system by a wireless link. The invention also provides a number of other advantages and benefits that should become even more apparent after reviewing the following detailed descriptions of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The nature, objects, and advantages of the invention will become more apparent to those skilled in the art after considering the following detailed description in connection with the accompanying drawings, in which like reference numerals designate like parts throughout, and wherein:

FIGURE 1A is a block diagram of hardware components and interconnections of a telecommunications system incorporating wireless links in accordance with one embodiment of the invention;

FIGURE 1B is a block diagram of a vocoder capable of implementing the present inventions encoding and decoding methods coupled to a prior art noticing apparatus in accordance with one embodiment of the invention;

FIGURE 2 illustrates a typical prior art TDD communication device used in accordance with one embodiment of the invention;

FIGURE 3 shows a traffic channel frame format for a rate set 1 used by a variable rate vocoder;

FIGURE 4 is a flow diagram of a method aspect in accordance with one embodiment of the invention;

FIGURE 5 illustrates a block diagram of a wireless telecommunication system configured according to an embodiment of the invention;

FIGURE 6 illustrates a block diagram of a wireless telecommunication system configured according to an embodiment of the invention; and

FIGURE 7 is a flow diagram of a method for controlling transmission power levels between a base station and a mobile station.

DETAILED DESCRIPTION OF SELECTED EMBODIMENTS

FIGURES 1 through 7 illustrate examples of various method and apparatus aspects of the present invention. For ease of explanation, but without any limitation intended, these examples are described in the context of a TDD communication device attached to a digital telecommunication system incorporating wireless links, one example of which is described below.

HARDWARE COMPONENTS AND INTERCONNECTIONS

FIG. 1 illustrates one type of telecommunications system 100 including wireless links and a TDD communication device (TDD) 200 as used in the present invention. As shown in detail in FIG. 2, TDDs usually include a keyboard and a display that are connected to a telephone via a modem (modulator/demodulator). The modem is built into the TDD and is either directly connected to a telephone line or coupled by an acoustic coupler to a normal telephone handset. TDDs are capable of transmitting information over telephone lines by means of coded tones to other TDDs, such as TDD 102 shown in FIG. 1, connected at opposite ends of a telephone line through another modem.

In digital telecommunications systems using wireless links, the TDD 200 may be coupled to a subscriber unit 104 that is used in the telecommunications system 100 to transmit received signals. Exemplary embodiments of a subscriber unit 104 are digital signal telephones, such as the Q-800 manufactured by Qualcomm Incorporated, and commonly referred to as cell phones. The subscribers unit 104 as shown in FIG. 1 includes a noticing apparatus 106 communicatively coupled to circuitry of the subscribers unit 104. A hardwire 108 may be used to connect the TDD 200 to the subscribers unit 104 via the noticing apparatus 106, or a device port may be used. Examples of such a noticing apparatus and device ports are disclosed in the U.S. Patent application entitled "**METHOD AND APPARATUS FOR ESTABLISHING TDD/TTY SERVICE OVER VOCODED CHANNELS**, serial number

09/114,344, filed July 13, 1998, assigned to the assignee of the present invention and incorporated by reference herein.

The device port may be configured to receive a low activity communication device attachment such as a plug, connector, or receiver. These items are commonly used today for connecting telephone and computer equipment, and are readily available from electronics suppliers. The device port interfaces with the attachment to communicatively connect a low activity communication device (not shown) such as the TDD 200 to the subscriber unit 104 of the telecommunications system100. The device port allows information to be exchanged between a low activity communication device and the subscriber unit 104. Regardless of whether a device port or a hardwire is used, the noticing apparatus 106 allows for the system 100 to be noticed that a TDD signal needs to be transmitted.

Returning to FIG. 1, after the noticing apparatus 106 receives the low activity communication signal, the signal is processed by the subscriber unit 104. Very basically, a signal for transmission is created that includes the information contained in the low activity signal. Because the telecommunications system 100 has been noticed that a low activity signal is being transmitted, the system adapts to assure a decipherable transmission occurs. For example, an analog signal received from the analog circuitry 228 shown in FIG. 2 normally would undergo signal or "voice" processing including digitizing the signal, setting a transmit power level to protect against signal fading during transmission, compressing the signal, and filtering. These functions may be performed by the circuitry (not shown) of the subscriber unit 104 that includes a vocoder. Depending upon the signal received, a variable rate vocoder – generically referred to in this application as a vocoder - may dynamically determine and negotiate service within the telecommunications system 100 to provide successful transmission and decoding of the signal. This negotiation involves establishing the values for multiple parameters, such as the rate the vocoder should use, the transmission power, and compression technique. A fuller discussion concerning the processing of signals for

transmission in telecommunication system may be found Electronic Industry Association standard TIA/EIA/IS-95-A entitled "Mobile Station-Based Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular Systems, referred to as "IS-95" and incorporated by reference herein, and other transmission standards, including standard vocoder protocol, are well known in the art.

However, when a low activity signal is received, a vocoder may identify the signal as either noise, a pause, or a signal not intended to be transmitted. Simply, a vocoder doesn't know what service to use because it cannot identify the low activity signal received. By noticing the system 100 that a low activity signal is being sent, the vocoder will establish the service needed to assure the best possible transmission and decoding of the signal.

After the low activity communication signal has been processed and the service determined, a signal may be transmitted using an antenna 112 over a wireless link 114. The digitized signal is received by another antenna 116 at a remote location, such as a base station 118, and processed by base station circuitry (not shown) including a vocoder 120. Various based station circuitry arrangements for telecommunications systems are well known in the art, and a further understanding may be found in TIA/EIA/IS-95-A referenced above. By processing the signal after receipt, a low activity signal reflecting the information contained in the transmitted low activity signal may be delivered to the low activity device 102 via communication link 120. A second noticing apparatus 106 is shown coupled to the base station 106. This provides for a low activity signal to be sent from the low activity communication device 102 back to the TDD communication device 200.

Communication link 120 appears bifurcated to emphasize that the base station 118 may not be connected directly to the low activity device 102. The base station 118 is usually connected to a standard PSTN switching station commonly used by telephone companies for coordination of telephone calls and the low activity device 102 is connected to the PSTN. In another embodiment, a second mobile station (not shown) connected to the low activity communication

device 102 may be linked to the base station 118. Further, the telecommunication system may include mobile switching stations as mentioned above.

Shown in FIG. 2 is a schematic block diagram of the circuitry of a typical TDD device 200, either a standard or enhanced TDD, operating in accordance with the present invention. In the TDD device 200 of FIG. 2, a keyboard 202 is provided into which the user may input data characters. The output of the keyboard 202 is connected to a processor 204 that serves to control the circuit elements contained in FIG. 2. Characters that are received or transmitted by the processor 204 are also displayed on a display 206. Optionally, the same characters received or transmitted may be reproduced on a device such as printer 208. Some TDD devices may not have a printer, although it standard for TDDs to have a visual display of some kind so that a user can see the characters being typed and received. The keyboard 202 thus functions as an input source of data characters to the processor 204 while either or both the display 206 and the printer 208 serve as local destinations for the data stream characters.

The processor 204 may be connected by a suitable data and address bus that would typically be used for this type of application by one schooled in the art. In FIG. 2, the bus 210 connects a read only memory (ROM) 212 to a non-volatile random access memory (NVRAM) 214. Appropriate control lines 216 and 218 are connected from the processor 204 to the ROM 212 and the NVRAM 214 providing interactive control of these units. The ROM 212 is intended to permanently store the program that dictates the operation of the processor 204 as well as certain data used by the program. For example, special character strings for machine-to-machine communication and for synchronizing two TDDs in an enhanced operating mode may be stored. The NVRAM 214 is used as a buffer, a floating storage place for data coming into or out of the TDD device 200, and for storage of standard messages as entered by the user through the keyboard 202 and intended for rapid. Other circuitry configurations may be used, such as combining the microprocessor 202 with the ROM 212 and the NVRAM 214 in a single integrated circuit.

Also connected to the processor 202 in FIG. 2 is a telephone keypad 220 that permits the entry of telephone numbers for dialing by the processor 202 through telecommunications system 100. A standard telephone handset 224 rests on a cradle 226 that incorporates a switch (not shown) indicating whether the handset 224 is in use and thus removed from the cradle 226.

The processor 204 is communicatively connected through analog circuitry 228 to the telecommunications system 100. This connection is shown as a hardwire connection 230, but may be any type of connection that can communicatively link the analog circuitry 228 with the telecommunications system 100. The analog circuitry 228 provides a connection between the handset and the processor 202 allowing both Baudot tones and dialing tones to be received by the telecommunications system 100. The analog circuitry 228 provides an interface of voice information to and from the handset 224. The analog circuitry 228 of the TDD device 200 is connected to the telecommunication system 100 using a connector such as the device discussed above.

Despite the specific foregoing descriptions, ordinarily skilled artisans having the benefit of this disclosure will recognize that the apparatus discussed above may be implemented in a telecommunications system of different construction without departing from the scope of the present invention. As a specific example, multiple subscriber unit 104 may be linked to the base station 118, or the low activity communication device 200 may be integrated with the subscriber unit 104.

OPERATION

After a TDD signal is received, vocoders used by the system 100 during processing of the signal are noticed or detect that a low activity signal has been received for transmission and may use an eighth rate traffic channel frame format to transmit the signal. However, adaptation of the following methods for quarter-to-full rate traffic channel transmissions may be accomplished, as discussed below.

FIG. 3 shows a typical variable rate vocoder frame format for a traffic channel using a rate set 1. The variable rate vocoder produces a frame every 20 milliseconds using Code Excited Linear Prediction (CELP) techniques that are well known in the art. The frames may be formatted in full, half , quarter or eighth rate formats depending upon voice activity. If a Baudot tone is received, the variable rate vocoder will usually detect low activity and use the eighth rate format, assuming the standard vocoder currently in use can detect that a signal is being sent. Commonly, a Baudot signal will be treated as noise and generally ignored.

Full rate refers to the fact that each bit contained in each frame is not repeated. Half-rate refers to sending the same number of bits per frame, but each bit is repeated once in the frame; that is, each unique bit will appear twice in the frame. Quarter-rate refers to each unique bit appearing four times per frame, and so on. The more repetitively a bit of information is sent, the less total information is sent per frame. At full rate the signal is sent at a higher power because a given bit is sent only once. This full rate power level is referred to as the reference power for purposes of this application. Because bits are repeated at lower rates, a reduced power level is used because the power for each repeated bit is accumulated over the frame. Assuming a fixed minimum power is used for the transmission, a full rate transmission will contain more frame errors than would a half rate transmission of the same information.

Typically, the power level is set based upon a selected frame error rate (FER) for the transmitted signal as received at a remote location, also referred to as the target of the transmitted signal, such as the subscriber unit. A desired FER is selected because when a low activity signal is being sent, the actual FER increases using current methods. This selected FER range is between a 0.1% and a 1.0% error rate, but may be greater or lesser if necessary for preservation of the quality of the transmitted signal. Preferably, an FER of 0.2% is desirable for low activity signals.

In the present invention, implementing specialized encoding and decoding techniques controls the frame error rate. In the circumstance that the

disclosed techniques fall short of a desired FER - in this case FER being defined as the total number of erred frames even after reconstruction of vocoder frame information – methods to adjust transmission power levels can also be used along with the specialized encoding and decoding techniques. Typically, the vocoders will be locked at full rate and the transmission power will be increased for transmitting low activity signals. It should be realized that any increase required would still be less than the increase required if the present encoding/decoding techniques were not implemented.

A. Decoder Using Soft Bits

In one embodiment, when a TDD call is received, the system 100 is either noticed or detects the call type. The system 100 processes the call from TDD unit 200 for transmission using standard processing techniques known in the art. When the frame is received at a remote point, for example base station 118, the call is decoded using the present invention. If a frame error has occurred in the physical layer, that is, if the frame does not pass the checksum as described within IS-95, the frame is still delivered to the vocoder 120 for decoding. Delivering the erred frame to the vocoder is currently not done in standard IS-95 implementations. Bits contained in an erred frame are referred to as "soft bits" because they may not all be in error and information may be gleaned from them individually to reconstruct information contained in erred frames.

However, detecting or being noticed that a TDD call has been received, the vocoder decoder in the present invention processes erred frames by looking at the vocoder parameters received and comparing these parameters against "signatures" of TDD modulation signals or tones as seen in the vocoder parameter space. This compares the vocoder parameters of stored vocoded TDD tones with those received. This comparison results in a determination being made as to which TDD signal was most likely received.

For example, suppose a vocoder representation of a Baudot tone of "0" is represented as sixteen "0"s in sequence, and that the representation of a Baudot tone of "1" is represented as sixteen "1"s. The present method

considers these to be voice-parameter-space signatures. For the following examples, three layers are identified as:

vocoder frame boundaries: | -- voc frame 'N' -- |
baudot tone boundaries: | -- baudot 'X' -- | , and
received vocoder parameter: 0000000000000000 or
1111111111111111.

Assume that the vocoder decoder receives the following parameters:

{erred frame}

| --voc frame 1 -- | --voc frame 2-- | --voc frame 3-- | --voc frame 4 -- | -- voc
t '1' -- | -- baudot '0' -- | -- baudot '0' -- | -- baudot '1' -- | -- baudot '0' -- |
111111100000000000000000000000000000000110000111111111111110000000000000000
^^^^^

[frame errors]

The decoder recognizes the baudot tone boundaries and recognizes that the received parameters for the second baudot '0' are closer to '0' than '1.' The decoder decides on baudot tone '0' and modifies the suspected error bits before decoding. For the next baudot tone '1,' the decoder recognizes that the vocoder parameters are closer to '1' than '0' and modifies the bits accordingly. The decoder now uses the following sequence to produce a corrected TDD signal:

{corrected frame}

| --voc frame 1 -- | --voc frame 2-- | --voc frame 3-- | --voc frame 4 -- | -- voc
t '1' -- | -- baudot '0' -- | -- baudot '0' -- | -- baudot '1' -- | -- baudot '0' -- |
111111100000000000000000000000000000000111111111111111111110000000000000000

This example shows the error transitions to occur at a frame boundary, which isn't always the case. If these transitions commonly fall within a frame, another version of the invention can be used as follows.

If the vocoder decoder receives an erred frame where the erred bits are contained within the frame, the vocoder may look to adjacent non-erred or "good" frames to reconstruct the erred frame. The adjacent frame will contain a

portion of the baudot tone that was lost in the erred frame. For example, suppose the following signal is received:

{erred frame}

```
| --voc frame 1 --| --voc frame 2-- | --voc frame 3-- | --voc frame 4 --| -- voc
t '1' --    | -- baudot '0' -- | -- baudot '0' --    | -- baudot '1' --  | -- baudot '0' --  |
111111110000000000111111111111111110000000000111111111111111111110000000000000000
                                          ^^^^^^^^^^^
```

[frame errors]

The vocoder parameters for the second baudot tone '0' are too ambiguous to make an accurate decision on the tone because the number of '0's is almost the same as the number of '1's in the vocoder frame parameters. To make a better determination, the vocoder looks at the next adjacent frame (voc frame 3) and determines that the tone appears to continue as a '0' into this frame. The decoder therefore decides that this is meant to be a baudot '0' tone in the latter half of vocoder frame 2.

As shown in the flow chart of FIG. 4, after it is determined if a low activity signal is being received in tasks 402 and 404, the decoder continuously monitors and updates the received baudot tone boundaries in task 408. Otherwise, any non-low activity signal is processed using traditional methods. If an erred frame is received as detected in the physical layer, the frame is assigned an indicator N and the vocoder examines the erred frame in task 410. If a "reliable" decision concerning whether or not the frame is a baudot '0' or '1' can be made, such as when the frame parameters are quite distinct, then the erred frame is modified to reflect the parameters of the decision. A reliable decision is one that falls within a prescribed probability of obtaining the original frame parameters. For purposes of this invention, the desired probability would be in the range of 51% to certainty. If a modification is made, the method returns to task 402 and determines the next signal.

If a reliable decision cannot be made as shown in task 412, the vocoder reviews the next adjacent frame N+1 or, alternatively, N-1. If this frame is good

in task 416, the decision to modify the erred frame is made in task 418 based upon the parameters contained within frame N+1, or alternatively, frame N-1. If neither next adjacent frame is good, then a next best reliable decision is made based upon the parameters contained within next adjacent frame N+1 and frame N's parameters are modified accordingly.

B. Encoder and Decoder Using Soft Bits

The decoder implementation in this embodiment of the invention is similar to that disclosed above. However, to further reduce the error rate and improve upon the accuracy and reliability of the signal decoded, the encoder also takes advantage of the "soft bits."

When the vocoder encoder detects baudot tones are to be sent, the encoder switches to a "baudot tone encoding mode." In this mode the encoder decides whether the tone received for encoding is a '0' or a '1.' The encoder then sends this decision to the decoder using a vocoder frame, but using channel-coding redundancy to improve the decoder's chances of determining the proper baudot tone. Even if the decoder receives a tone in an erred frame, it will have a greater likelihood of determining the correct tone sent because of the forwarded decision.

In a simplified example, if the encoder detects a baudot '1' is to be transmitted, it sends a series of 1s to the decoder. The series may be any length, but must be sufficient so that the decoder can operate as discussed above in section A if necessary. This version of the invention replaces the standard vocoder parameters with vocoder "signatures" that are better spaced apart (i.e., easier to differentiate), thus making it easier to decide between two tones even when frames are in error.

C. Encoder and Decoder Not Using Soft Bits

This embodiment of the invention is another version of the methods described in sections A and B, but the decoder is not given the soft bits from any erred vocoder frames to process.

In this case, when the vocoder encoder detects a '1' or '0' baudot tone, the vocoder also encodes the tone in a vocoder frame using redundancy, but the encoding may be done across many vocoder frames. The '1's and '0's are interleaved across a number of frames M so that if one frame is lost, the decoder can extract the necessary information from adjacent frames. The following example shows interleaving taking place across four frames, but any number of frames could be used. Assume the encoder detects the following baudot tones for transmission:

1 1 0 0 1

The encoder encodes the frames as follows for transmission to the decoder:

| --voc frame 1 -- | --voc frame 2-- | -- voc frame 3 - | --voc frame 4 -- | -- voc frame 5

|-- baudot '1' -- | -- baudot '1' -- | -- baudot '0' -- | -- baudot '0' --- | -- baudot '1' –

xxxxxxxxxxxx1111xxxxxxxx11111111xxxx111111110000111111110000000011110 00000001111 .

In this example, the vocoder frame parameters for each frame are segmented where four bits represents the detected baudot tone in a particular vocoder frame. The entire sixteen bits represents the detected baudot tones from the last four vocoder frames:

| baudot for frame N-3 | baudot for frame N-2 | baudot for frame N-1 | baudot for frame N | .

To account for baudot tones not corresponding to vocoder frame boundaries, the invention uses the following four-bit sequence where XXYY indicates that the code in the current vocoder frame reflects a baudot code of 'X' followed by a baudot code of 'Y':

| --voc frame 1 -- | --voc frame 2-- | --voc frame 3 -- | --voc frame 4 -- | - voc

t '0' -- | -- baudot '1' -- | -- baudot '1' -- | -- baudot '0' -- | -- baudot '0' -- |

xxxxxxxxxxxxx0011xxxxxxxx00111111xxxx00111111110000111111110000001111

D. Modified Vocoder with Increased Transmission Power

In another embodiment, the prohibitive cost of modifying the chipset in a mobile station to accomplish the encoding and decoding processes discussed above in sections A, B and C is advantageously minimized.

The encoding and decoding methods of sections A, B and C can be advantageously accomplished through the use of a standard vocoder connectively communicating with a signal enhancer, such as an estimator or a repeater or any other device capable of performing a signal enhancing function. In addition, the methods of sections A, B, or C can be accomplished through the use of a modified vocoder. It would be apparent to one skilled in the art that a vocoder can be modified to further incorporate the functions of a signal enhancer, i.e., to make an estimation of whether corrupted bits received by the communication unit were originally transmitted as '0's or '1's.

The system of FIG. 5 illustrates one embodiment of the invention. The transmission from base station 550 to mobile station 510 is referred to as the forward link and the transmission from the mobile station 510 to the base station 550 is referred to as the reverse link. In the reverse link, unmodified vocoder 520 in mobile station 510 encodes the Baudot signal into standard vocoder parameters and transmits the vocoder parameters to base station 550. Modified vocoder 560 receives the encoded Baudot signal and enhances the Baudot signal to restore corrupted bits. A clean version of the Baudot signal is then generated. In the forward link, unmodified vocoder 580 in base station 550 encodes the Baudot signal using standard vocoder parameters and transmits the vocoder parameters to mobile station 510. Modified vocoder 530 receives

the encoded Baudot signal and enhances the Baudot signal to restore corrupted bits. A clean version of the signal is then generated.

However, using signal enhancers or modified vocoders on both the forward link and the reverse link to accomplish the decoding methods discussed in sections A, B, and C can be prohibitively expensive to produce. In yet another embodiment of the invention, the frame error rate of the system can be reduced by using a signal enhancer in a base station on the reverse link, and by using power control techniques to adjust signal transmission power levels from the base station to the mobile station on the forward link.

In the reverse link of the communication system of FIG. 6, base station 655 reconstructs the original Baudot signal contained within a vocoder encoded frame according to the methods discussed in sections A, B and C. However, in the forward link, base station 655 transmits the encoded Baudot signal using power control techniques as discussed in U.S. Patent Application No. 09/114,344, entitled "METHOD AND APPARATUS FOR ESTABLISHING TDD/TTY SERVICE OVER VOCODED CHANNELS," assigned to the assignee of the present invention and incorporated by reference herein.

FIG. 7 is a flow diagram of a method for controlling transmission power between the base station and the mobile station. The method begins in task 702, where a Baudot signal is received by the mobile station 605. After the signal is received, vocoders used by mobile station 605 during processing of the signal are locked into a full rate in task 704. In this embodiment, the transmission power does not decrease from the transmission power used by the telecommunications system for full rate transmissions in task 710. The power level is typically set based upon a selected FER for the transmitted signal as received at the mobile station 605. A desired FER is selected because when a Baudot signal is being sent, the actual character error rate of the Baudot signal is about 9 to 10 times that of the FER. This selected FER range is between a 0.1% and a 1.0% error rate, but may be less if necessary for preservation of the quality of the transmitted signal. Preferably, an FER of 0.2% is desirable for transmitting Baudot signals. If the FER exceeds the selected range in task 712,

mobile station 605 notifies base station 655 in conventional fashion during task 706 that a system adjustment to reduce the FER is needed. Accordingly, an adjustment is made in task 708. An adjustment typically includes increasing the transmission power for the full rate transmission, but may also include adjusting other parameters known to reduce FER. If the FER is acceptable in task 712, the signal transmission may continue in task 714 and dynamic adjustments to the telecommunications system continue throughout the transmission of the entire transmitted signal 710. Otherwise, when the transmission of the Baudot signal ends, the vocoders are unlocked, and the telecommunications system returns to normal operation.

OTHER EMBODIMENTS

While there have been shown what are presently considered to be preferred embodiments of the invention, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the scope of the invention as defined by the appended claims.

What is claimed is:

CLAIMS

1. A method for communicating a noticed low activity communication signal in a telecommunication system, the telecommunication system including mobile stations and base stations, the method comprising:

transmitting an original frame represented by an original sequence of bits;

receiving a first transmitted frame, the first transmitted frame comprising a first transmitted sequence of bits, the first transmitted sequence of bits sequenced substantially the same as the original sequence of bits;

enhancing the first transmitted sequence of bits to produce an enhanced sequence of bits; and

processing the enhanced sequence of bits to obtain additional information used to identify the original sequence of bits in the original frame.

2. The method recited in Claim 1, wherein the step of processing the enhanced sequence of bits further comprises:

comparing the enhanced sequence of bits with a known low activity communication signal bit sequence;

determining whether the enhanced sequence of bits is statistically reliable; and

if the enhanced sequence of bits is statistically reliable, then modifying the enhanced sequence of bits to identify the original sequence of bits in the original frame.

3. The method recited in Claim 1 wherein the enhanced sequence of bits is labeled frame N and the step of processing the enhanced sequence of bits further comprises:

comparing the enhanced sequence of bits with a known low activity communication signal bit sequence to produce a comparison result;

if the comparison result indicates statistical reliability,

then modifying the enhanced sequence of bits based upon the comparison result to reflect the known low activity communication signal bit sequence;

but if the comparison result is not statistically reliable,

then processing a frame N+1 neighboring the frame N to determine if the frame N+1 contains any errors;

but if the frame N+1 is errorless:

then determining a low activity communication signal defined by a bit sequence contained in frame N+1; and

modifying the enhanced sequence of bits of frame N based upon the bit sequence contained in frame N+1.

4. The method recited in Claim 3, wherein said comparison results indicate statistical reliability if the probability that the known low activity communication signal bit sequence will reflect the original sequence of bits is 51% or greater.

5. The method recited in Claim 1, wherein the step of transmitting the original frame is performed by a mobile station and the step of receiving the first transmitted frame is performed by a base station.

6. The method recited in Claim 1, wherein the method further comprises the step of replacing standard vocoder encoding/decoding parameters used by a plurality of vocoders with vocoder signatures, wherein sequenced bits contained within the vocoder signatures are spaced further apart than sequenced bits contained within standard vocoder parameters, said replacement step preceding the transmitting step.

7. The method recited in Claim 6, wherein the step of replacing standard vocoder parameters further comprises:

communicating to a first vocoder that a low activity communication signal is being transmitted; and

encoding the low activity communication signal with a second vocoder, the second vocoder determining if a bit is a 0 or a 1, the encoding performed using channel coding redundancy within an information bit field of the original frame to improve the first vocoder's likelihood of decoding the original frame, the encoding also noticing the first vocoder that a low activity signal is being transmitted.

8. The method recited in Claim 6, wherein the step of processing the enhanced sequence of bits further comprises the steps of:

comparing the enhanced sequence of bits with a known low activity communication signal bit sequence; and

modifying the enhanced sequence of bits based upon the comparison to identify the original sequence of bits.

9. A method for communicating a noticed low activity communication signal in a telecommunication system, the telecommunication system including mobile stations and base stations, the method comprising:

transmitting a first original frame from a mobile station, wherein the first original frame is represented by a first original sequence of bits;

receiving a first transmitted frame at a base station, the first transmitted frame comprising a first transmitted sequence of bits, the first transmitted sequence of bits sequenced substantially the same as the first original sequence of bits;

enhancing the first transmitted sequence of bits within the base station to produce an enhanced sequence of bits;

delivering the enhanced sequence of bits to a first vocoder within the base station;

processing the enhanced sequence of bits with the first vocoder to obtain additional information used to identify the first original sequence of bits in the first original frame; and

transmitting a second original frame from the base station at an increased transmission power level.

10. The method recited in Claim 9, wherein the step of transmitting the second original frame from the base station at an increased transmission power level further comprises the steps of:

locking all vocoders used in processing the second original frame into a full rate; and

transmitting the second original sequence of bits at an increased transmission power level to maintain a minimum target frame error rate for the second original sequence of bits.

11. The method recited in Claim 9, wherein the enhanced sequence of bits is labeled frame N and the step of processing the enhanced sequence of bits further comprises:

comparing the enhanced sequence of bits with a known low activity communication signal bit sequence to produce a comparison result; and

if the comparison result indicates statistical reliability,

then modifying the enhanced sequence of bits based upon the comparison result to reflect the known low activity communication signal bit sequence;

but if the comparison result is not statistically reliable,

then processing a frame N+1 neighboring the frame N to determine if the frame N+1 contains any errors;

if the frame N+1 is errorless:

determining a low activity communication signal defined by a bit sequence contained in frame N+1; and

modifying the enhanced sequence of bits of frame N based upon the bit sequence contained in frame N+1.

12. The method recited in Claim 11, wherein said comparison results indicate statistical reliability if the probability that the known low activity communication signal bit sequence will reflect the original sequence of bits is 51% or greater.

13. The method recited in Claim 11, wherein the step of transmitting the second original frame from the base station at an increased transmission power level further comprises the steps of:

locking all vocoders used in processing the second original frame into a full rate; and

transmitting the second original sequence of bits at an increased transmission power level to maintain a minimum target frame error rate for the second original sequence of bits.

14. The method recited in Claim 13, wherein the minimum target frame error rate is less than 1.0%.

15. Apparatus for communicating a low activity communication signal in a telecommunication system, the apparatus comprising:

means for encoding an original frame of the low activity communication signal into an original sequence of bits;

means for transmitting the original sequence of bits;

means for receiving a first transmitted frame, the first transmitted frame comprising a first transmitted sequence of bits; and

means for enhancing the first transmitted sequence of bits with a signal enhancer to produce a clean signal.

16. The apparatus recited in Claim 15, wherein the apparatus further comprises:

means for comparing the enhanced sequence of bits with a known low activity communication signal bit sequence;

means for determining whether the enhanced sequence of bits is statistically reliable;

means for checking the statistical reliability of the enhanced sequence of bits; and

means for modifying the enhanced sequence of bits to identify the original sequence of bits in the original frame.

17. Apparatus for communicating a noticed low activity communication signal in a telecommunication system, the apparatus comprising:

a vocoder for encoding an original frame of the low activity communication signal into an original sequence of bits;

a transmitter for transmitting the original sequence of bits;

a receiver for receiving a first transmitted frame, the first transmitted frame comprising a first transmitted sequence of bits; and

a signal enhancer for enhancing the first transmitted sequence of bits to produce a clean signal.

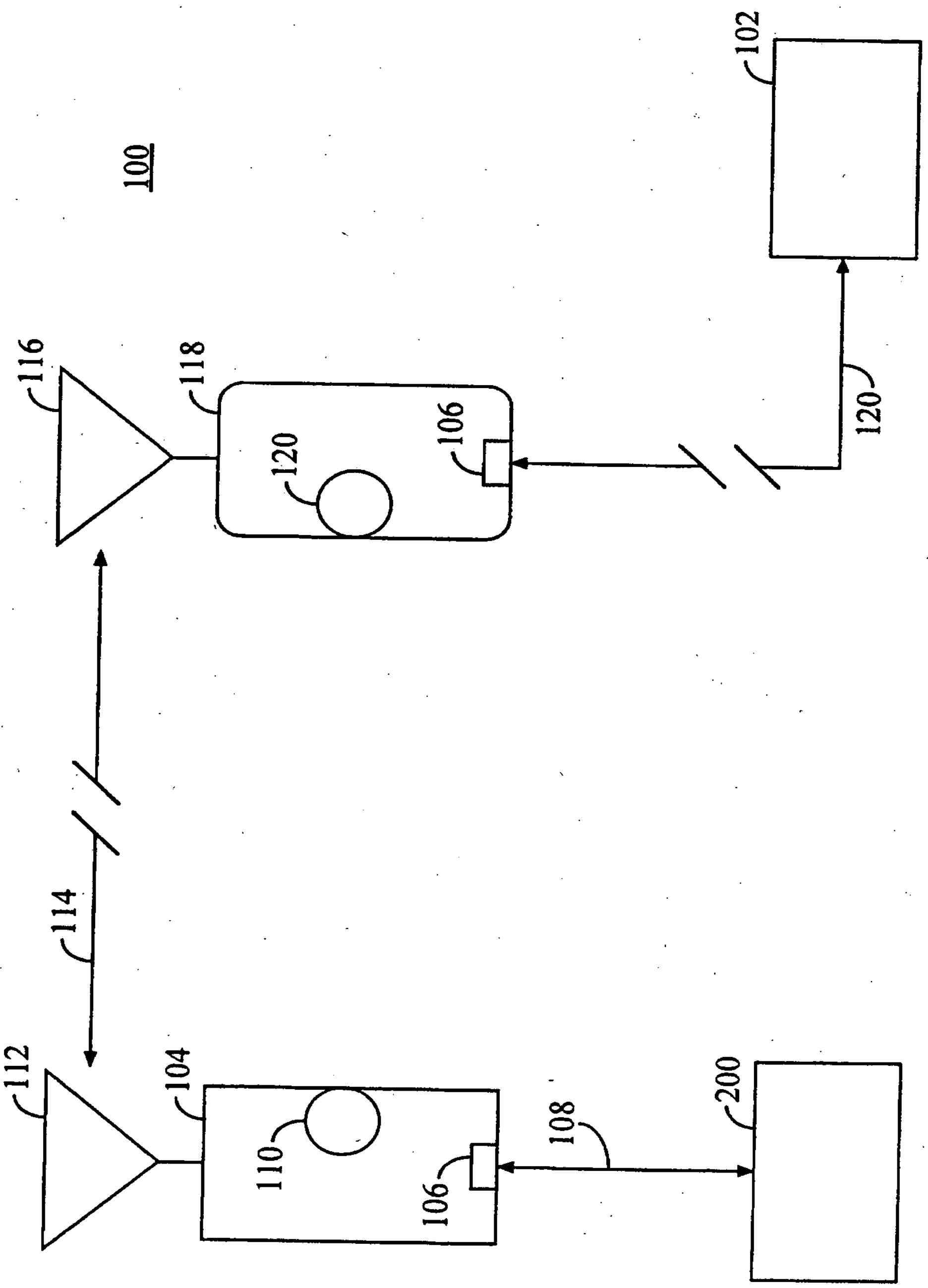
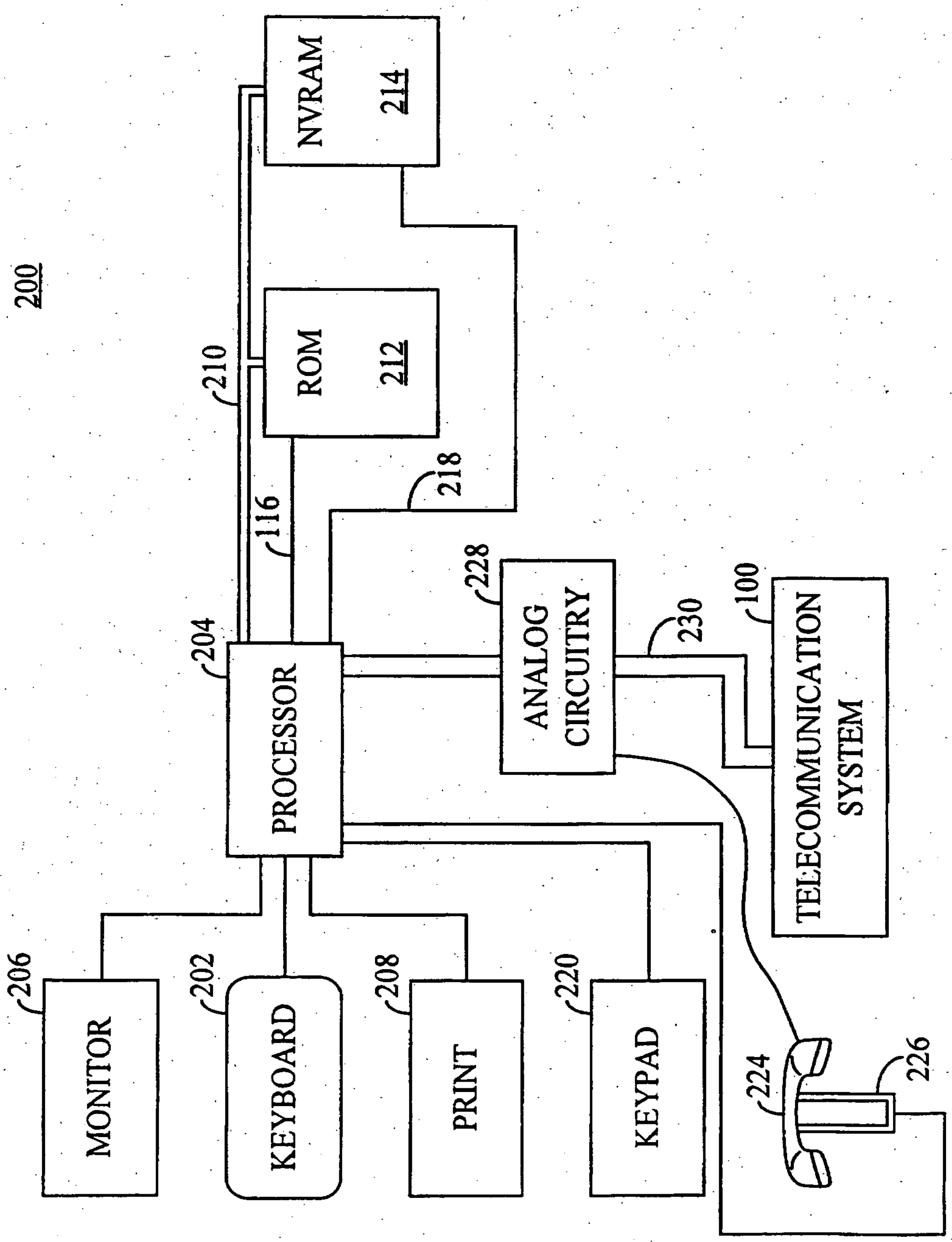


FIG. 1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NVRAM
214
ROM
212
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116
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PROCESSOR
228
ANALOG
CIRCUITRY
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TELECOMMUNICATION
SYSTEM
206
MONITOR
202
KEYBOARD
208
PRINT
220
KEYPAD
224
226

FIG. 2

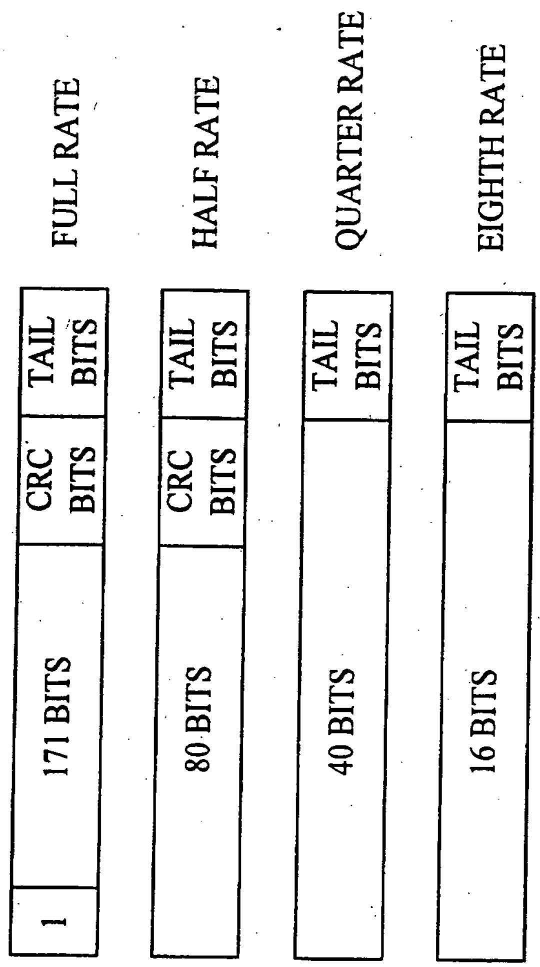
FULL RATE
1
171 BITS
CRC BITS
TAIL BITS
HALF RATE
80 BITS
CRC BITS
TAIL BITS
QUARTER RATE
40 BITS
TAIL BITS
EIGHTH RATE
16 BITS
TAIL BITS

FIG. 3

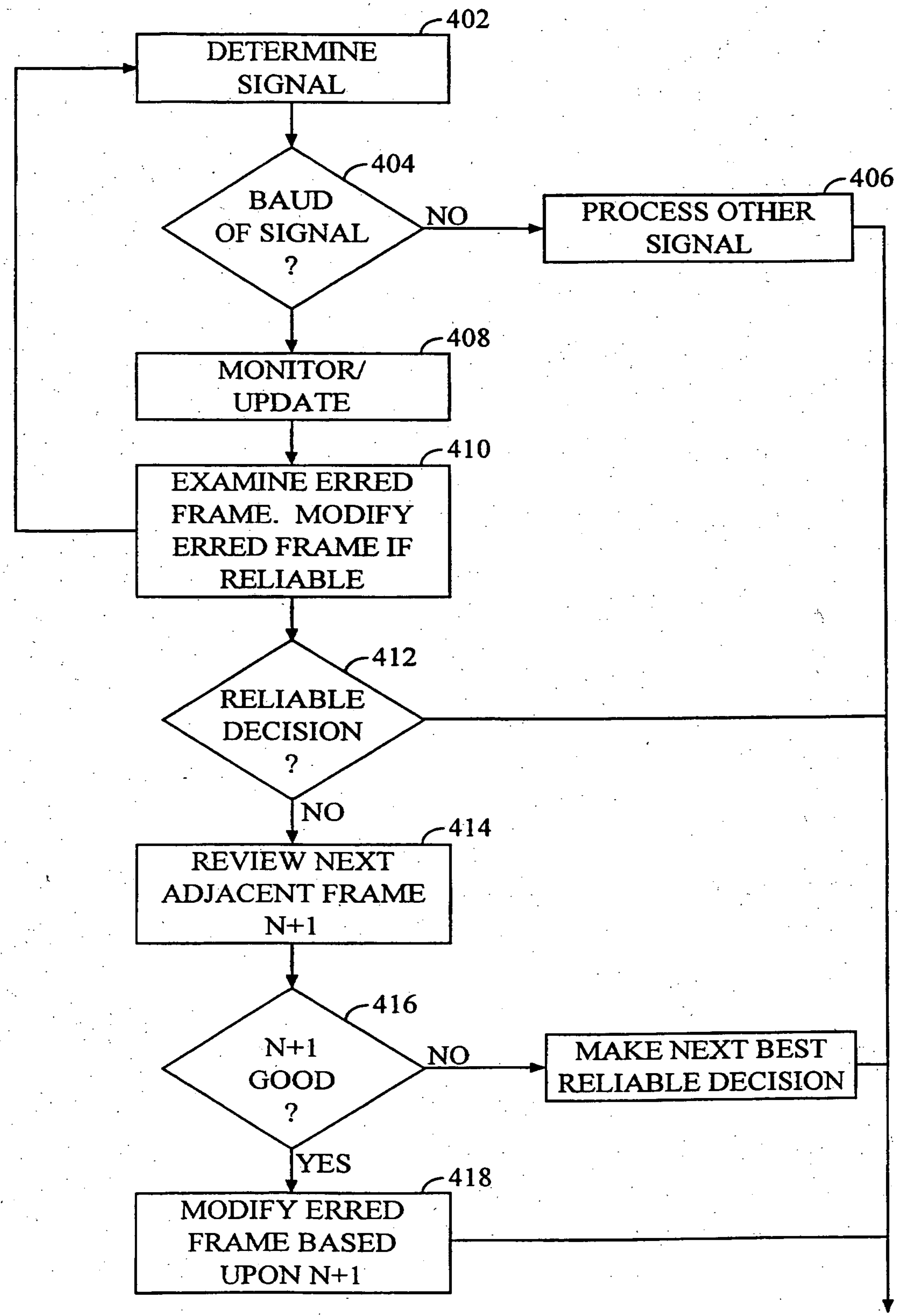
402
DETERMINE SIGNAL
404
BAUD OF SIGNAL ?
NO
406
PROCESS OTHER SIGNAL
408
MONITOR/ UPDATE
410
EXAMINE ERRED FRAME. MODIFY ERRED FRAME IF RELIABLE
412
RELIABLE DECISION ?
NO
414
REVIEW NEXT ADJACENT FRAME N+1
416
N+1 GOOD ?
NO
MAKE NEXT BEST RELIABLE DECISION
YES
418
MODIFY ERRED FRAME BASED UPON N+1

FIG. 4

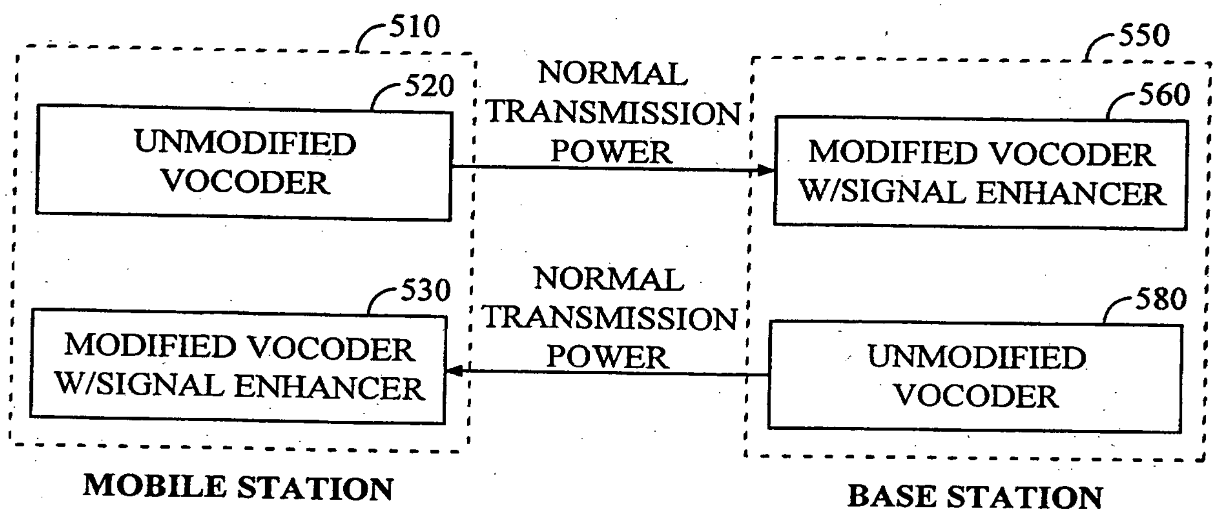
510
520
UNMODIFIED VOCODER
NORMAL TRANSMISSION POWER
550
560
MODIFIED VOCODER W/SIGNAL ENHANCER
530
MODIFIED VOCODER W/SIGNAL ENHANCER
NORMAL TRANSMISSION POWER
580
UNMODIFIED VOCODER
MOBILE STATION
BASE STATION

FIG. 5

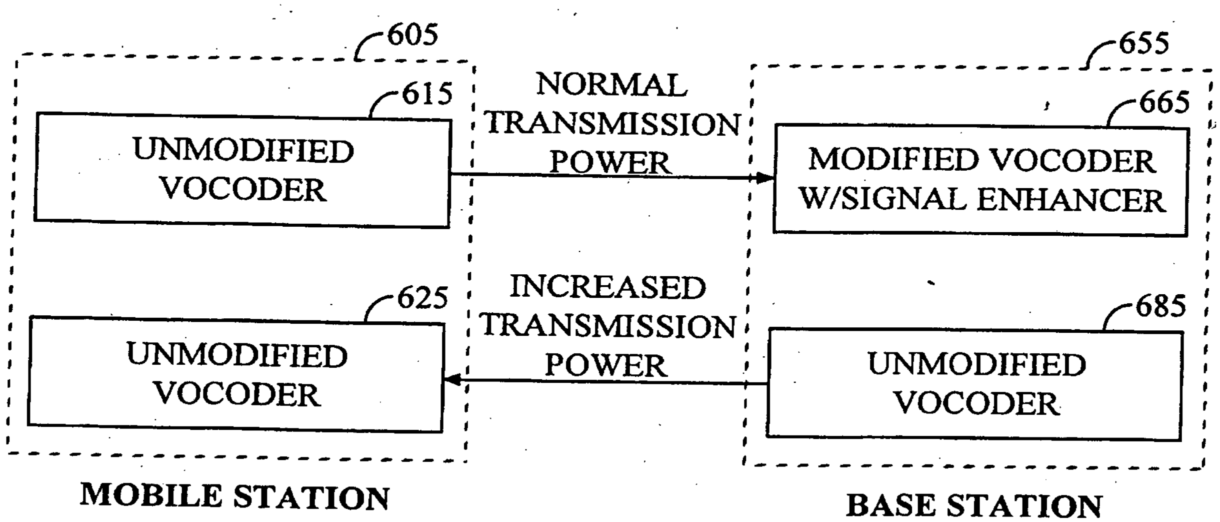
605
615
UNMODIFIED VOCODER
NORMAL TRANSMISSION POWER
655
665
MODIFIED VOCODER W/SIGNAL ENHANCER
625
UNMODIFIED VOCODER
INCREASED TRANSMISSION POWER
685
UNMODIFIED VOCODER
MOBILE STATION
BASE STATION

FIG. 6

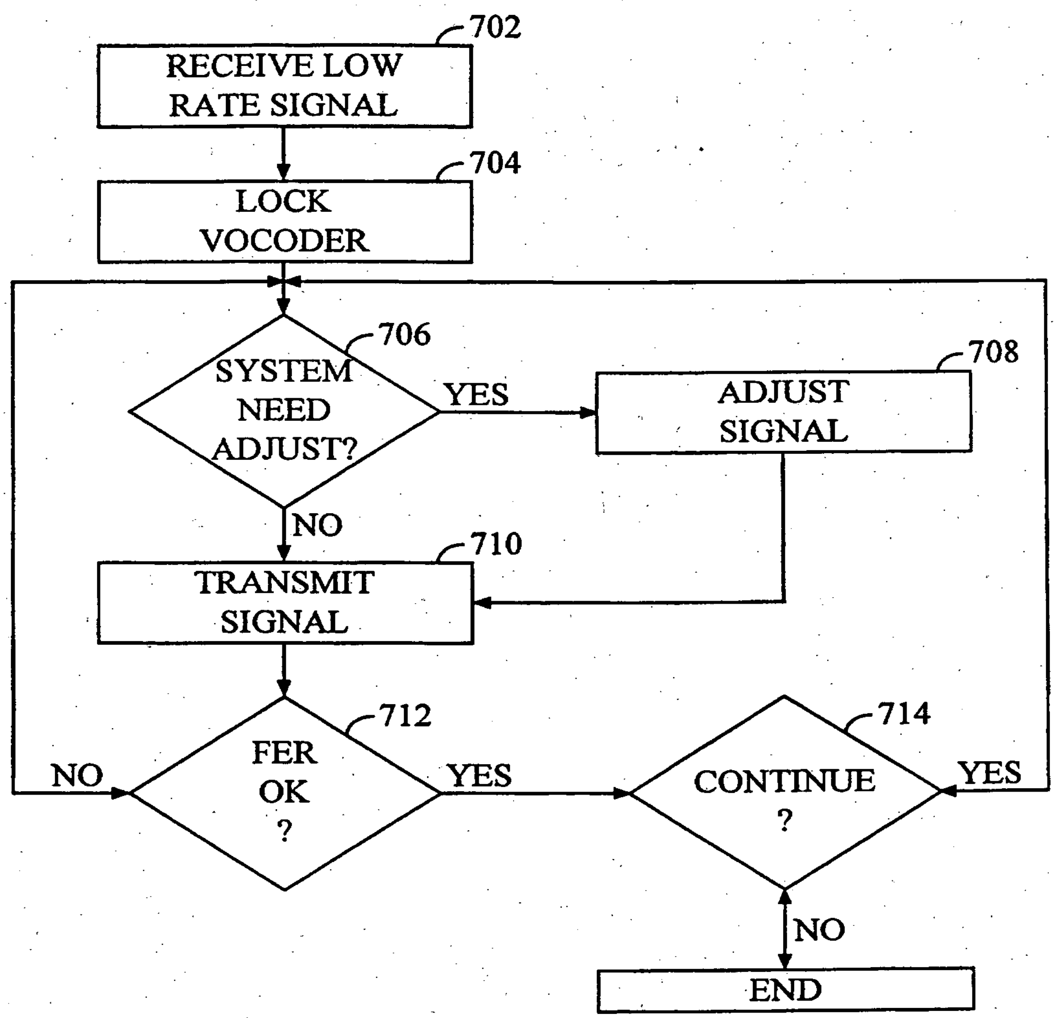
702
RECEIVE LOW RATE SIGNAL
704
LOCK VOCODER
706
SYSTEM NEED ADJUST?
YES
708
ADJUST SIGNAL
NO
710
TRANSMIT SIGNAL
712
FER OK ?
NO
YES
714
CONTINUE ?
YES
NO
END

FIG. 7

INTERNATIONAL SEARCH REPORT

Interr   ıal Application No
PCT/US 00/21441

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L17/00 H04L12/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04M H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 27758 A (DIVA COMMUNICATIONS ;KAVALER ROBERT (US)) 25 June 1998 (1998-06-25) page 9, line 18 -page 10, line 8 page 11, line 17 -page 14, line 3 page 16, line 23 -page 19, line 6 page 23, line 21 -page 25, line 23 ---	1-3,5,6, 8,15,17
X	WO 96 32817 A (NOKIA TELECOMMUNICATIONS OY ;VIRTANEN ANU (FI)) 17 October 1996 (1996-10-17) page 9, line 21 -page 10, line 7 page 12, line 2 -page 16, line 32 ---	1,2,5,6, 8,15-17
X,P	EP 0 982 904 A (LUCENT TECHNOLOGIES INC) 1 March 2000 (2000-03-01) the whole document --- -/--	1,15-17

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 November 2000	21/11/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gerling, J.C.J.

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/21441

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 93 23947 A (ULTRATEC INC) 25 November 1993 (1993-11-25) -----	

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/21441

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			CN	1261235	A	26-07-2000
			JP	2000092135	A	31-03-2000
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			CA	2113840	A	25-11-1993
			DE	69329054	D	24-08-2000
			EP	0596079	A	11-05-1994
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			US	5724405	A	03-03-1998